



George C. Marshall Space Flight Center  
Marshall Space Flight Center, Alabama 35812

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**Project Plan**

**For**

**Fastrac Engine**

**2<sup>nd</sup> Generation RLV Investment Area**

**ADVANCED SPACE TRANSPORTATION  
PROGRAM OFFICE (ASTP)  
TD15**

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## FASTRAC 60K ENGINE PROJECT PLAN

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## FASTRAC 60K ENGINE PROJECT PLAN

### 1.0 SCOPE

1.1 Identification. The Fastrac 60K Engine is developed under the auspices of the Fastrac 60K Engine Project (FEP). This engine will provide the primary propulsion system for the initial flights X-34 Experimental Vehicle.

This Fastrac 60K Engine Project Plan provides information for the organizational structure, responsibilities, procedures, process, and resources for implementing the Fastrac 60K Engine development. This plan determines the design process required to meet technical requirements and the needs of our customers. Our customers are the X-34 Program and the Advanced Space Transportation Program Office.

The Project Manager is responsible for maintenance of this plan. Any proposed revision to this manual is submitted to the Project Manager for authorization and subsequent incorporation after approval per TBD.

Other elements of ASTP related to the Fastrac 60K Engine are the Lox/RP Propulsion Test Article (PTA1) and associated avionics and a Horizontal Test Facility (HTF). PTA1 is a stand alone test article design to provide system level testing of low cost propulsion system components including the Fastrac 60K Engine. These include feed and pressurization systems, tanks, and avionics. The HTF is an engine test stand configured to simulate the X-34 application. Additional testing is planned at the Santa Susanna Test Facility, California utilizing the Alfa 1 test position.

1.2 Background. The NASA Office of Aerospace Technology (OAT) supports space research and development through sponsorship of technology programs conducted at the NASA Field Centers, in United States industry, and in American universities. The Marshall Space Flight Center Space Transportation Directorate (STD) supports OASTT by

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executing the NASA Lead Center roles assigned to MSFC for X-33, X-34, and the Advanced Space Transportation Program (ASTP).

Guidance and policy for FEP are derived from the National Space Transportation Policy (NSTC-4, 8/5/94), the National Space Policy (9/19/96), the NASA's Strategic Plan 1997 Final Draft (6/17/97), and the NPG 7120.5A.

FEP is chartered to enable liquid propulsion technologies which will significantly reduce the cost of access to space. Presently, high launch costs remain the central barrier to exploration of near earth space. The space launch community has approached an asymptotical limit to low cost space access. Until this limit is broken, the possibilities of space development will continue to be bounded. For example, launch cost are often several times the cost of small research and scientific payloads; with constant funding levels, decreasing the cost of launch systems will allow funds to be directed toward more advanced research and development applications.

The Fastrac 60K Engine is part of the overall cost reduction effort. The engine will be government furnished equipment (GFE) to the X-34 Project where the technology can be demonstrated in a test flight environment.

1.3 Summary. The FEP will develop the Fastrac 60K Engine system, verify that it meets all engine requirements including those of the X-34 Project and certify the engine for flight on an experimental vehicle. LCT will assist the X-34 Project in integration of the Fastrac 60K Engine into the X-34 Vehicle.

The FEP is chartered to demonstrate the use of cost reducing design and operation techniques such as simple engine system design, reduced part count, use of commercial off the shelf (COTS) components, and adaptation of commercial manufacturing techniques and standards to the aerospace engine application. The Fastrac 60K Engine will demonstrate the use of low cost technologies to the greatest extent possible without

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adding undue risk to the X-34 Project. Other propulsion components will be tested in PTA1.

Other objectives of the FEP will be pursued concurrent with the development of the Fastrac 60K Engine. These include developing a fast-track approach for demonstrating technology using product development teams, and rapid transfer of technology to industry for commercial product improvement and implementation.

The FEP is to coordinate technology development with other NASA projects. Pursuant to this the FEP is teaming with the X-34 Project to provide the main engine to the X-34 Project. The FEP will explore the use of low cost technologies in other application such as large boosters and upper stages.

## 2.0 APPLICABLE DOCUMENTS

MSFC-MQM      Marshall Quality Manual  
NPG 7120.5A NASA Program and Project Management Processes  
&  
                 Requirements

## 3.0 LIST OF ACRONYMS/ABBREVIATIONS

ART	Advanced Reusable Technologies
ASTP	Advanced Space Transportation Program
CDT	Component Development Teams
CE	Chief Engineer
CM	Configuration Management
CDR	Critical Design Review
CWC	Collaborative Work Commitment
COTS	Commercial Off The Shelf
DB	Design Binder
ECR	Engineering Change Request
FEP	Fastrac 60K Engine Project
FMEA	Failure Mode and Effects Analysis
FRR	Flight Readiness Review
GFE	Government Furnished Equipment
GG	Gas Generator
HTF	Horizontal Test Facility
LCT	Low Cost Technologies
LVA	Lines, Valves and Actuators

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MMI            Marshall Management Instructions  
 MPS            Main Propulsion Systems  
 NMI            NASA Management Instructions  
 NPG            NASA Procedures and Guidelines  
 NSTC           National Space Transportation Policy  
 OASTT        Office        of        Aeronautics        and        Space  
 Transportation Technology  
 O&M           Operation & Maintenance  
 PDR            Preliminary Design Review  
 PDT            Product Development Teams  
 PRR            Preliminary Requirements Review  
 PTA1           Propulsion Test Article  
 QMS            Quality Management System  
 RID            Review Item Discrepancies  
 RPTMB        Rocket Propulsion Test Management Board  
 SIT            System Integration Team  
 SSC            Stennis Space Center  
 STP            Space Transportation Programs  
 STR            Space Transportation Research  
 STT            In-Space Transfer  
 TCA            Thrust Chamber Assembly  
 TRR            Test Readiness Review  
 WWW           World Wide Web

#### 4.0            OBJECTIVES

Reduce space transportation cost and improve reliability by sponsoring research and technology demonstration of a low cost engine system. Encourage commercialization and use of the Fastrac 60K Engine by demonstrating system viability in flight tests on the X-34 Experimental Vehicle.

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## 5.0 MANAGEMENT

5.1 Organization and Responsibilities. The Fastrac 60K Engine development will be implemented by Product Development Teams (PDT), and Component Development Teams (CDT). All teams will be cross functional and comprised of all disciplines needed to design, analyze, fabricate, and test all hardware. The teams will be staffed from NASA personnel as required to respond to project requirements. Contracted support may be used with the permission of the Project Manager. The teams are empowered to develop the test articles within the guidelines established in this project plan. The organizational structure is shown below in Figure 1.

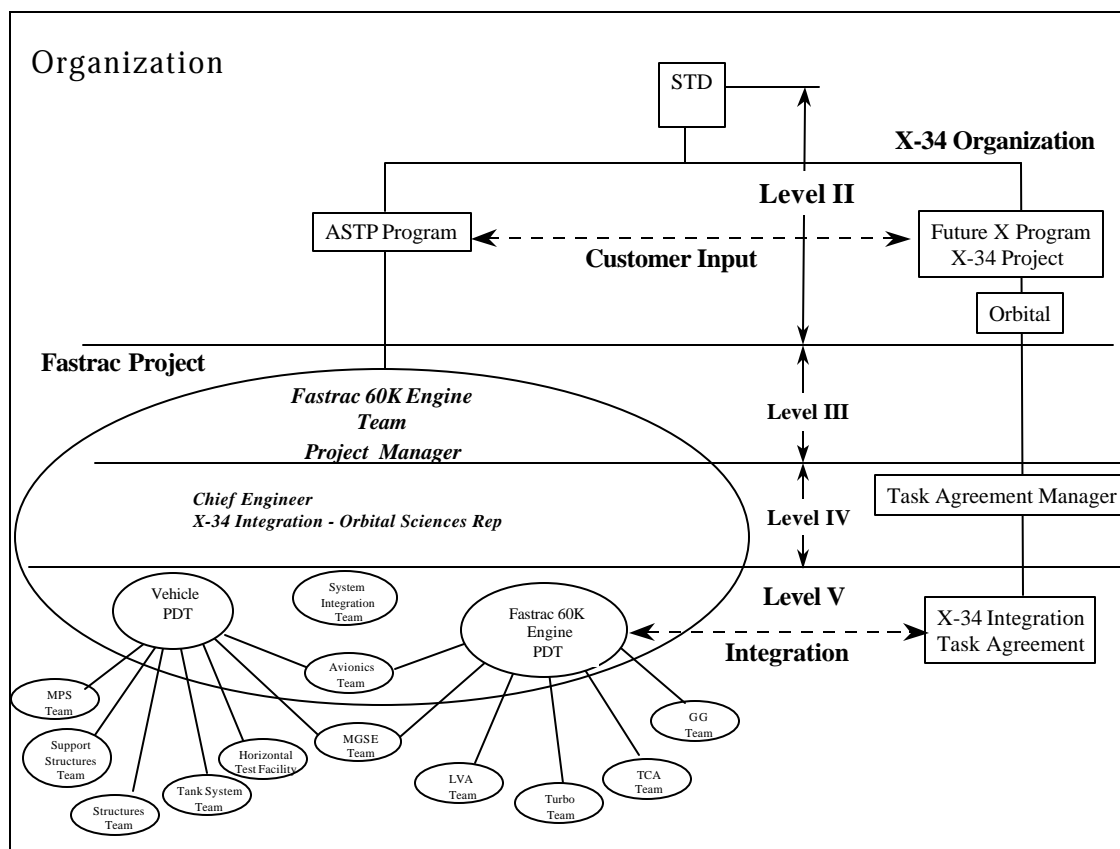


Figure 1. Fastrac Engine Organization.

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5.1.1 Program Management (Level II). Over all Program management is provided by the Space Transportation Directorate. A Level II Control Board is in place to provide program oversight and resolve issues between ASTP and the X-34 Project. This board is chaired by the STD Director and includes as a minimum the Future X Program Manager, The ASTP Program Manager, and a customer representative from Orbital.

5.1.2 Project Management (Level III). The Project Manager is assigned by MSFC's ASTP office and reports to the ASTP Program Manager (Level 2). The Project Manager is responsible for developing an approach to meet the objectives established by the ASTP Program Manager; developing lower level project constraints such as budget, resources, and schedule; and implementation planning that coordinates NASA and contractor assets. The products of the Project manager are:

1. Project Plan
2. Integrated Project Schedule
3. Collaborative Work Commitments (CWC) Requesting Organization Inputs

The Project Plan shall be written per NPG 7120.5A.

The Integrated Project Schedule shall be developed using Microsoft Project and will contain all tasks identified by the PDTs and project management. The tasks shall be logically linked with the critical path identified.

The Project Manager shall report progress to Program Management monthly or as required by Project events.

The Project Manager is assisted by a Deputy Project Manager. The Deputy Project Manager will be the primary interface between the FEP and the X-34 Project. The Deputy Project Manager will also provide COTR support and documentation for contracts that support the Project. Other duties of the Deputy Project Manager include assuring resolution of technical and programmatic issues and reporting to the Project Manager. .

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5.1.3 Engineering Management (Level IV). The Lead System Engineer and Assistant Engineer are assigned by ASTP and functionally report to the Project Manager. The CE's are responsible to the project for ensuring that all aspects of the project engineering activities, including in-house and contractor responsibilities, are accomplished within the technical requirements and cost and schedule constraints. The Fastrac 60K Engine CE's provide system engineering leadership to PDT activities and participate in the decision making process as necessary to ensure technical adequacy of the project throughout the design, development, and implementation, and preside over a Level 4 Board consisting of the Chief Engineers, and the PDT leads. The CE's will work in conjunction with the Project Manager to assure manpower is adequately applied to the Project via the CWC system.

The products of the Chief Engineers are:

1. CWC Performing Organization Inputs and coordination.
2. Level 4 directives releasing drawings, documentation; and change control documentation.
- 3.
4. Design review agendas, review team coordination, and pre-board disposition.

The CE is supported by the System Integration Team which is described in Section 8.1.

5.1.4 Product Development Teams - Component Development Teams (Level V). The Product Development Team (PDT) approach will expedite development of technology by allowing design decisions to be made by a small group of engineers who are cognizant of the product requirements, design, schedule, and budget. The Component Development Teams (CDTs) and PDTs are responsible for all aspects of product development including design, analysis, fabrication, test, quality, safety, and test flight assurance. Each PDT and CDT is responsible for assuring that their product meets the design requirements and will interface with the other products developed during the project. To perform this function, the teams will be

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cross-functional with all engineering, safety, quality, and test (Stennis Space Center - SSC) disciplines represented as required. The CDTs and PDTs are chartered by the Fastrac Project Office and will, as a minimum, contain membership from the disciplines shown in Section 8.1.1 of this document. The CDTs and PDTs are empowered to develop the products within the minimum project requirements and guidelines specified in this document.

The CDTs and PDTs respond to project requirements, determine what tasks are to be accomplished, and determine the schedule for completion of these tasks per guidelines set by the Fastrac 60K Engine Project Manager. The PDTs will meet as a team and determine the best way to meet program requirements including performance, cost, and schedule. The PDTs are responsible for documenting their design in an electronic Design Binder per the outline shown in this document. CDTs will be responsible for developing component specifications to fully document the design requirements of each component.

The Fastrac PDTs and CDTs will be staffed via the "product oriented" organizations at MSFC and SSC. Other than the personnel assigned to the ASTP Office, all members to the Fastrac Team will continue to report to the line organization for direction. Review Board members will be assigned by MSFC management and will consist of technical personnel at the management level.

The PDT Leads are responsible for coordinating team activities, determining product requirements, establishing what tasks are to be done and the schedule, determining the verification of requirements, and identifying any issues within or across the PDT's, informing the Chief Engineer of the issues, and resolving the issues. The PDT Leads are also responsible for assuring the design schedule is being met and the Chief Engineer and Project Manager are aware of progress and slips.

Products of the PDTs and CDTs are:

1. The assigned product verification and acceptance documentation
2. Inputs and regular update to the Project Schedule
3. Detailed Design Binder documentation
4. Weekly status updates

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5.1.5 X-34 Integration Team (Level V). The LCT PDTs and CDTs work jointly with the X-34 Integration Team to provide interface definition and engine operation interface to the X-34 vehicle developers.

5.2 Special Boards and Committees. The Project Manager shall schedule independent reviews with technical experts not associated with the development activity. These reviews will coincide with the design reviews.

5.3 Management Support Systems. A schedule development expert assists the Project manager. This support will coordinate development of an integrated project schedule with input from the PDT/CDT leads and the CE. The Project Manager will use MSFC's MARTS system to track project funding obligation and costs, and work force expenditures.

## 6.0 RELATIONSHIP TO OTHER PROGRAMS

A primary mission of FEP is to coordinate technology development with other NASA Projects. Pursuant to this, the FEP is teaming with the X-34 Project of the Pathfinder Program to provide the engine to the X-34 Vehicle. The FEP will develop a low cost engine system and verify that it meets the requirements of the X-34 Project and is certified for flight on a test vehicle. The FEP will assist in integration of the Fastrac 60K Engine into the X-34 Vehicle.

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## 7.0 TECHNICAL SUMMARY

7.1 Project - Level Requirements. Detailed Level II requirements shall be developed and managed in a PTA1/60K Fastrac Engine Requirements/Verification/Compliance Database by the SIT. Requirement flow down is illustrated in Figure 2 below.

### Fastrac Engine Design Requirements Tree

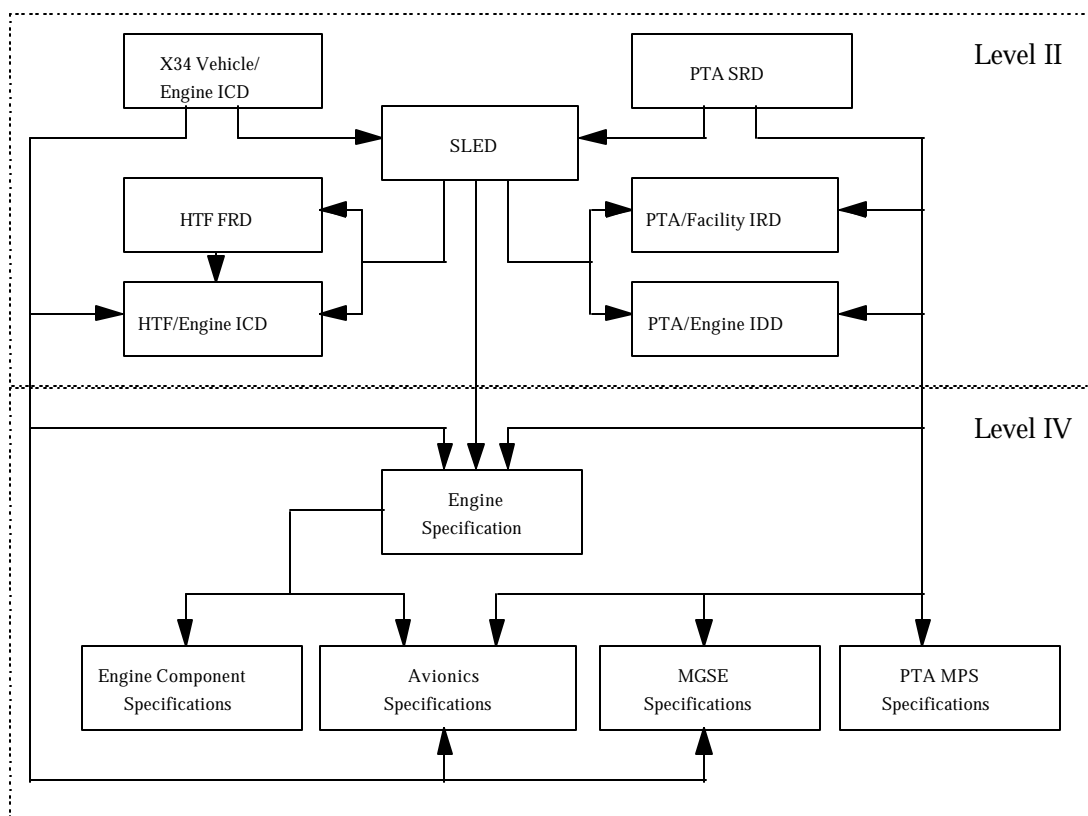


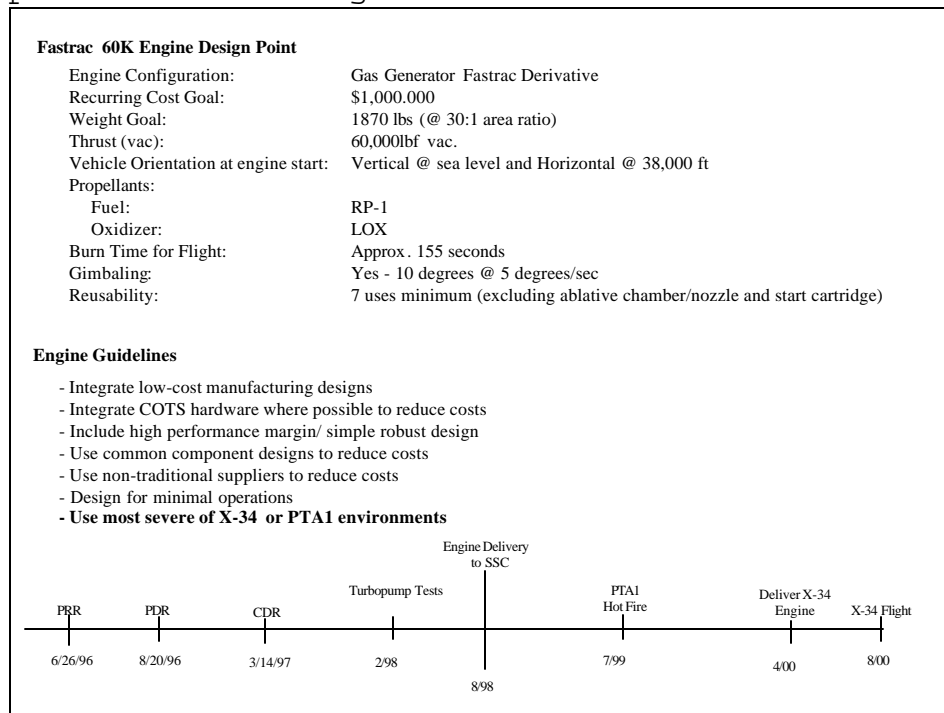
Figure 2. Requirements Flow Down.

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#### 7.1.1 Fastrac 60K Engine Requirements.

1) Provide an experimental test flight engine to X-34 Project per memorandum of agreement for delivery of the Fastrac Engine and the X-34 Vehicle/Fastrac 60K Engine Interface Control Document.

2) Develop a low cost engine based on the design point shown in Figure 3 below.



**Figure 3. Fastrac 60K Engine Design Point.**

#### 7.1.2 PTA1 Requirements.

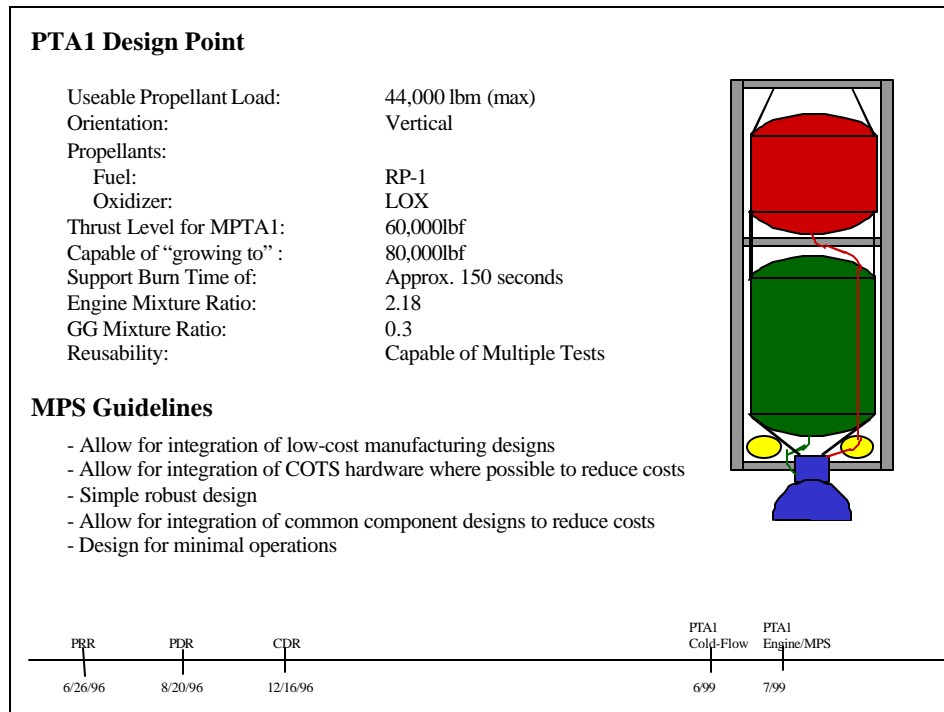
1) Provide a LOX/RP propulsion test article (PTA1) that incorporates low-cost technologies and demonstrated their operation in ground tests.

2) Provide measurements necessary for estimation of Fastrac 60K Engine specific impulse.

3) Provide avionics for command, checkout, control, and data acquisition of the PTA1 and Fastrac 60K Engine.

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The PTA1 design point, shown below in Figure 4, applies to mechanical and electrical components included in the test article.



**Figure 4. PTA1 Design Point.**

### 7.1.3 Risk Mitigation Requirements.

1) Provide additional hardware, analysis, and capability to minimize the following risks:

a) Provide a minimum of two independent engine test facility to mitigate loss of test capability. Detailed requirements for each facility shall be developed by the SIT and approved by the Project Manager.

b) Provide a test facility tot simulate horizontal pre-flight orientation and flight operations to mitigate system failure during X-34 operations.

c) Provide appropriate test and flight spare hardware to minimize impact of loss of test hardware.

d) Provide appropriate analysis and tests to mitigate risk of design error.

e) Provide engineering to support configuration management planning to mitigate risk of configuration control error.

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7.2        System(s).    The Fastrac 60K Engine system is to be developed using technologies from previous technology projects - the Fastrac I and II TCA Projects and the Simplex Turbopump Project. The engine will use an ablative chamber/nozzle and a simple gas generator cycle that is open-loop controlled and calibrated via orifice sizing. The engine will not include an on-board controller. Control is supplied by an off mounted avionics system (supplied by PTA1 for engine system level tests and by the X-34 vehicle for integrated ground tests and flight tests). Engine components will be tested in component test stands at MSFC, system level testing will occur at the Stennis Space Center (SSC) or alternate test facilities as determined by the Rocket Propulsion Test Management Board (RPTMB). Integrated propulsion system ground testing in the X-34 vehicle will be performed by the X-34 Project in a static ground test article. An engine with a 30:1 expansion ratio nozzle will be supplied for this test. A Fastrac Engine fitted with a 30:1 nozzle will be supplied for use in the X-34 flight test. Additional start cartridges will also be supplied to support the flight tests.

7.3        System Operations Concept.    Engine Operations & Maintenance (O&M) Manuals and Engine Hot Fire Specification are developed by the Engine PDT detail the procedures necessary to prepare the engine for use and to operate the engine. The engine will be installed into the test facility and tested by test facility personnel. The engine will be removed and refurbished by test facility personnel. The refurbishment includes removal and replacement of the ablative chamber/nozzle, removal and replacement of two start devices, and check out of the refurbished engine. Removal and replacement procedures will be done in accordance with the O&M manuals. The FEP will ship an engine, spare nozzle, and start devices to X-34 Project as required to support the X-34 milestones (per MOA Fastrac 60K to X-34 dated 8/22/96).

7.4        System Constraints.    Not Applicable

7.5        Ground Systems and Support.    Ground support equipment requirements will be developed and

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hardware designed and fabricated by the GSE CDT to support all engine operations and electrical checkout. This includes transportation and handling of all engine and PTA components and assemblies. The GSE must be available for engine assembly at SUMMA, component testing at MSFC, system level testing operations at SSC and alternate test sites,. The X-34 Project will impose additional GSE requirements via a separate X-34 task agreement to support X-34 operations. This team will strive to provide commonality with all GSE designs.

7.6 Facilities. Component testing will be performed at MSFC's test stand 116. System level testing at an SSC approved Facility. PTA1 will originally reside in the B-2 test stand. An alternate position (E-2 Cell 2) will be provided when B-2 is no longer available. HTF will be located on the B2 test stand in the vicinity of the PTA1 and will be developed per MSFC-RQMT-2720. The HTF may share ground systems with PTA1. An alternate vertical position will be identified by SSC for testing while HTF and PTA are not available or as required to meet Project schedules.

7.7 Logistics A Logistic Plan will be developed by the Engine and PTA PDTs. This plan will encompass all functions of logistics applicable to the Fastrac 60K Engine project including: maintenance, Operation & Maintenance documentation, material and supply support, packaging and transportation, training, facilities, and base technical and institutional support. It will define in general terms, the Project's logistics requirements and will specify the Project and contractor requirements, responsibilities, and methods for logistics support. Flight engines will be considered Program Critical Hardware (PCH) after acceptance procedures and will be handled according to TBD.

7.8 Mission Results Analysis and Reporting. Each PDT/CDT shall provide data reviews for all tests shortly after a test series is completed. The records and actions of each review shall be maintained by the Engine System PDT lead. The Engine PDT shall collect and store engine test data collected from SSC during system level tests and provide a data review package after each

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test series is complete. Any data identified in the PTA1/60K Fastrac Engine Requirements/Verification/Compliance Database as required verification data will be supplied to the SIT. The PDT/CDTs will analyze engine data collected during flight.

Each PDT/CDT shall develop a cost report for their product which lists the following cost parameters:

First unit production cost

25<sup>th</sup> unit production cost

The following categories and goals will be addressed:

<b>Element</b>	<b>25<sup>th</sup> Unit Cost Goal</b>	<b>Learning Curve %</b>
Nozzle (including nozzle brackets)	\$ 75,000	95
Main Injector	\$ 48,500	90
Gas Generator	\$ 20,000	90
Ignition Systems	\$ 15,600	90
Engine Lines (including orifices)	\$ 74,000	90
Engine Valves	\$ 178,000	95
Turbopump Assembly	\$ 360,000	95
Brackets and Misc. Hardware	\$ 39,000	90
Instrumentation and Cabling	\$ 14,000	90
Engine Assembly	\$ 36,000	95
Engine Acceptance Tests	\$ 70,000	95
Total	\$930,100.00	

The following ground rules apply:

25<sup>th</sup> production unit estimates based on the Crawford learning curve percentages shown above.

No amortization of development cost included in recurring cost estimates.

12 units produced per year.

Use vendor quotes when possible, assume full cost accounting rates for government production related activities.

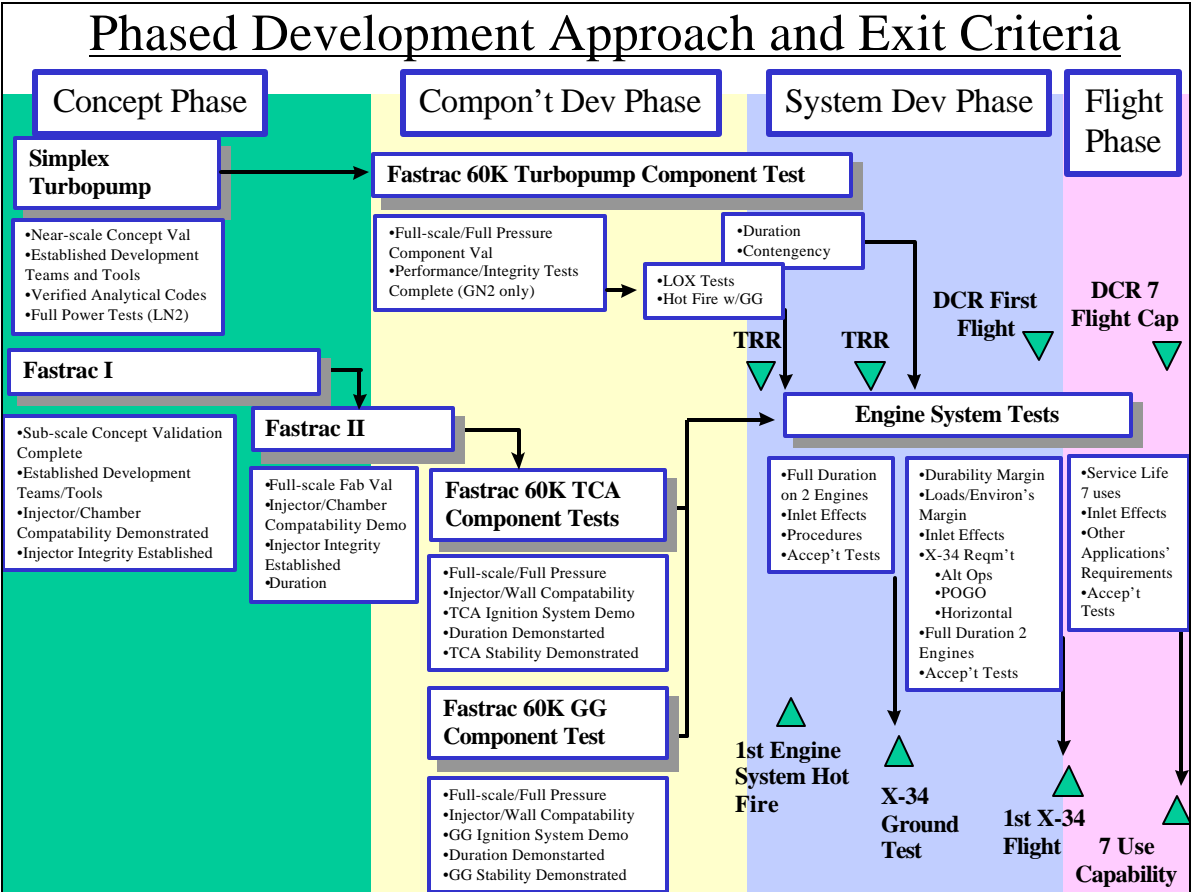
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## 8.0 TASK DESCRIPTIONS

8.1 Implementation Approach. The FEP is an experimental project intent on understanding the use of low cost hardware in a space transportation application. History has shown how the lack of understanding constraints on design in an experimental project sometimes means failure in test—this is especially true when alternate technology approaches are being studied. Therefore, the project recognizes the possibilities for success while acknowledging that failure may occur until the limit of low cost design is truly understood. To minimize project risk, alternate and less risky designs will also be developed in parallel to some low-cost experiments. (see section 15.0)

To minimize the impact of failure, a phased approach will be taken. First, component level tests are performed to build a technology base and to develop mature component designs. System level ground demonstrations and finally flight demonstrations follow these tests. Figure 5 illustrates the phased approach and exit criteria for the major engine components and engine system.

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**Figure 5. Phased Development Approach and Exit Criteria.**

Fastrac development is not funded for formal qualification typical of traditional manned engine programs described in TBD. No test article(s) will be designated as a qualification unit that is formally qualified. A detailed Certification Plan will be developed by the Engine team based on the guidelines shown in Figure 5. This plan will determine what verification data establishes that the engine is certified for flight on the X-34 Vehicle and must be approved by the Project Manger. Certification requirements will be maintained in a Certification Database which is maintained by the Engine team. The Certification Plan shall identify verification data and documentation format for each PDT/CDT to comply with. Certification is not complete until all open item are

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closed and the Design Certification Review (DCR) is complete.

All engine test articles will be configured as close to the flight engine configuration as possible. Test data collected on engines configured differently from the flight configuration may be applied to certification if analysis supports the applicability of the data to verification of a requirement. The Fastrac engine designated for X-34 flight will be acceptance tested prior to shipment.

The FEP stresses that the immediate application of these low-cost technologies is limited to un-manned flight of inexpensive payloads. Reliability will not be demonstrated due to limited test articles, tests and flight experience.

To maximize testing, the design and fabrication processes will be streamlined to emphasize proof of concept testing for both ground and flight component technologies. The LCT project has been empowered to meet the objectives of the program in the "best possible way". This has enabled this project to set new precedents in design, manufacturing, and testing. MMI's (Marshall Management Instructions) and NMI's (NASA Management Instructions) and subsequent publications are to be used as guidelines as opposed to requirements on the project. This does not mean that the program is not responsible for assuring the safety of the hardware, personnel, and facilities; it does however, allow for the design process to be streamlined while still maintaining the intelligence conveyed through past experience.

#### 8.1.1 Development Teams.

The Fastrac 60K Engine and associated test articles shall be developed under the organization requirements shown in section 5.0. The Development Teams described in the following section are chartered to implement the design, analysis, and testing of the project hardware. Manufacturing will be procured primarily from outside sources. In-house fabrication may be used when available. These teams are to be staffed with government employees where possible. Contracted personnel may be

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used with the permission of the Project Manager but the Project is primarily an in-house effort.

8.1.1.1 System Integration Team. The System Integration Team (SIT) is responsible for:

1. Interface Control - including definition, documenting, and verification.
2. Mass Properties
3. Configuration Control - The SIT assist the CE in the configuration management process. The main product of the SIT is systems process and analysis which leads to verifiable hardware, built to program approved drawings. The results of these activities will be documented in the Design Binder. A detailed configuration management plan shall be developed by the SIT per MPG 8040.1.
4. System Requirements - The SIT supports the CE in developing system requirements consistent with the guidelines stated in this Project plan. The SIT will develop an electronic requirements and verification database (PTA1/60K Fastrac Engine Requirements, Verification, and Compliance Database) for the system level requirements. The database shall show for each requirement the verification method and document compliance. The database shall be maintained by the SIT and controlled by the Level II Board. S&MA shall maintain the compliance section of the database as a Quality Record per MPG 1441.1A and held for a period of five years after the last X-34 powered flight. The SIT shares the responsibility of the overall effectiveness of Fastrac 60K Engine requirements integration with the PDT leads. In addition, the SIT will develop a process and a database for use by the design PDTs and CDTs in establishing the tracability between the system level requirements and the components specifications. The SIT will maintain the database, but the design PDTs are responsible for establishing the tracability between the lower level requirements documents and the systems level documents as well as populating the database.
5. Verification - per above
6. Instrumentation and Electrical Power Roll-up
7. EMI/EMC and Lightning Protection
8. Review Support - The SIT is responsible for assisting the CE in managing design reviews (PRR, PDR, CDR, TRR and DCR). Review Item Discrepancies (RIDs)

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generated in the review process shall be controlled by the Engineering Directorate as a Quality Record per MPG1441.1A for a period of five years after the last X-34 powered flight.

8.1.1.2 Engine Product Development Team. The Engine PDT is responsible for developing the Fastrac 60K Engine per the guidelines stated in this Project plan, the X-34/Fastrac 60K Engine ICD, and the Systems Requirements Document. This task includes the system engineering, design, analysis, design integration, and test integration of the engine. This team will provide detailed test requests to the test facility. In addition this team is responsible for the safety and quality aspects of the engine. The Engine PDT shall develop a Fastrac 60K Engine Specification as requirements for engine and component development and provide a verification report to document compliance with requirements. The Engine team is responsible for developing the engine Certification Plan and organizing and presenting compliance data at the DCR. The Engine team is responsible for development certification, flight acceptance, and delivery of one Fastrac 60K engine to the X-34 Project. The results of these activities will be documented in the Design Binder. The team membership must include as a minimum, the following disciplines:

- Team Lead
- Engine Systems Specialist
- Mechanical Design
- Turbomachinery Representative
- TCA Representative
- GG Representative
- Lines, Valves & Actuators Representative
- MSFC Safety
- MSFC Quality Assurance Representative
- Structures and Dynamics Specialist
- Materials and Processes Specialist
- Systems Integration Representative
- Avionics PDT Representative
- PTA System/Test Facility PDT Representative

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## Instrumentation Specialist

The Engine PDT is supported by the following four CDTs

8.1.1.3 Turbomachinery Component Development Team. This team is chartered to develop low cost solutions to turbomachinery requirements stated in this Project plan and in the Fastrac Engine Specification. The Turbomachinery CDT will design, fabricate, and test a low cost turbopump to be integrated and tested as part of the Fastrac 60K Engine. This CDT shall develop a Fastrac 60K Engine Turbopump Component Specification and provide a verification report to document compliance with requirements. Key opportunities for cost reduction are in innovative use of existing low cost manufacturing, use of COTS materials, use of common manufacturing techniques.

As a minimum, the following disciplines will be members of the CDT:

- Team Lead (Turbopump Design Lead)
- Design and Analysis Coordination
- Mechanical Design
- Stress Analysis
- Thermal Analysis
- Computational Fluid Mechanics Specialist
- Rotodynamics Analysis
- Material Selection Specialist
- Manufacturing Specialist
- System Safety Specialist
- Component Test Specialist

8.1.1.4 Thrust Chamber Assembly (TCA) Component Development Team. This team is chartered to develop low cost solutions to chamber/nozzles, injectors, and main chamber igniter requirements stated in this Project plan and in the Fastrac Engine Specification. This CDT will design and fabricate low cost experiments to be integrated and tested as part of the Fastrac 60K Engine. This CDT shall develop a Fastrac 60K Engine TCA Component Specification and provide a verification report to

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document compliance with requirements. Key opportunities for cost reduction are in innovative use of existing low cost manufacturing, use of COTS materials, use of common manufacturing techniques. As a minimum, the following disciplines will be members of the TCA CDT:

- Team Lead
- Nozzle Design Lead
- Injector Design Lead
- Mechanical Design (Injector and Nozzle)
- Stress Analyst
- Thermal Analyst
- Computational Fluid Mechanics Specialist
- Material Selection Specialist
- Manufacturing Specialist
- System Safety Specialist
- Component Test Specialist

8.1.1.5 Gas Generator (GG) Component Development Team. This team is chartered to develop low cost solutions to gas generators, and GG igniter requirements stated in this Project plan and in the Fastrac 60K Engine Specification. This CDT will design and fabricate low cost experiments to be integrated and tested as part of the Fastrac 60K Engine. This CDT shall develop a Fastrac 60K Engine GG Component Specification and provide a verification report to document compliance with requirements. Key opportunities for cost reduction are in innovative use of existing low cost manufacturing, use of COTS materials, use of common manufacturing techniques. As a minimum, the following disciplines will be members of the GG CDT:

- Team Lead (GG Design Lead)
- Mechanical Design
- Stress Analyst
- Thermal Analyst
- Computational Fluid Mechanics Specialist
- Material Selection Specialist
- Manufacturing Specialist
- System Safety Specialist
- Component Test Specialist

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8.1.1.6 Lines, Valves and Actuators Component Development Team (LVA CDT). This team is chartered to develop low cost solutions to engine lines, valves, and actuator requirements stated in this Project plan and in the Fastrac Engine Specification. The LVA CDT will design and fabricate low cost experiments to be integrated and tested as part of the Fastrac 60K engine. This CDT shall develop a Fastrac 60K Engine Valve and Lines Specification(s) and provide a verification report to document compliance with requirements. Key opportunities for cost reduction are in innovative use of existing low cost manufacturing, use of COTS materials, use of common manufacturing techniques. As a minimum, the following disciplines will be members of the Lines, Valves and Actuators CDT:

- Team Lead (LVA CDT Lead and Valve Design)
- Line and Duct Design
- Mechanical Design
- Stress Analysis
- Thermal Analysis
- Material Selection Specialist
- Manufacturing Specialist
- System Safety Specialist
- Component Test Specialist
- Avionics PDT Representative

8.1.1.7 PTA1 Systems. The PTA1 Systems PDT is responsible for developing the PTA1 propulsion components, the HTF, and any alternate facility, tankage and line structure analysis and coordination, support structure review, coordinating integration of avionics, and test integration with Stennis Space Center (SSC) and SSC contractors. This team will provide any facility/PTA1 specific test requests inputs to the engine PDT for inclusion into the test request. In addition this team is responsible for the safety and quality aspects of the test article. This team includes membership as broken-down by component below and representatives from SSC. The component teams, with the exception of the support structures team, are chartered to

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develop low cost solutions to the design of booster propulsion and structures hardware. The results of these activities will be documented in the Design Binder. It is to be noted, however, that the requirements of the program and other constraints related to developing a test article must take precedence over actual flight design solutions. The spirit of low cost approach should be adhered to and sought, but the design must follow the letter of the requirements regarding the design of PTA test article.

Team Lead  
Engine PDT Representative  
Test Article Integration and Test (Stennis Space Center)  
Ground Support Equipment PDT Representative  
Avionics PDT Representative  
System Integration  
Tankage Structures  
MPS  
Industrial Safety Specialist  
MSFC Quality Assurance Representative

8.1.1.8 Main Propulsion Systems Component Development Team (MPS CDT). This team is chartered to develop low cost solutions to launch vehicle propellant delivery, pressurization, fill, drain, and vent requirements. The MPS CDT will design and fabricate low cost experiments to be integrated and tested as part of the PTA1 test article. This team will also review the test facility designs for all other facility solutions to assure facility requirements and engine interface requirements will be met. Key opportunities for cost reduction are in innovative use of passive systems that eliminate the need for some components, use of COTS valves (or slightly modified COTS valves), use of COTS tubing and duct materials and low cost manufacturing. The team will be responsible for meetings the requirements of the test facility and providing a safe test article for the project. This team will use all MSFC and support contractor personnel required to ensure success. As a minimum, the following disciplines will be members of the MPS CDT:

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Team Lead  
 Propulsion System Analyst  
 Mechanical Design of Fluid Components  
 Stress Analyst  
 Tank Design  
 Thermal Analyst  
 Material Selection  
 Manufacturing

8.1.1.9      Tankage Structures Component Development Team. This team is chartered to develop low cost solutions to launch vehicle structural requirements. The tankage structures CDT will design and fabricate low cost experiments to be integrated and tested as part of the PTAl test article. Key opportunities for cost reduction are in innovative use of existing low cost manufacturing, use of COTS materials, use of common manufacturing techniques. The team will be responsible for meetings the requirements of the test facility and providing a safe test article for the project. Reusability and ground safety of this hardware may preclude use of flight like structures. As a result low cost techniques will not be demonstrated at the exact design point specified for flight structure. It is hoped that extrapolation of the design and manufacturing concepts will illustrate cost benefits of the design approach. This team will use all MSFC and support contractor personnel required to ensure success. As a minimum, the following disciplines will be members of the Tankage Structures CDT:

Team Lead  
 Structural Design  
 Stress Analyst  
 Loads Analyst  
 Thermal Analyst  
 Material Selection Specialist  
 Manufacturing Specialist

8.1.1.10      Support Structures Component Development Team. This team is chartered to design and fabricate the support structure for the PTAl. This hardware will not

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be part of the low cost experiment but will be made to accommodate a wide variety of experimental change-out. This team will assure that the support structure for the PTAl is adequately designed such that it will induce life limiting loads to the PTAl. This team will use all MSFC and support contractor personnel required to ensure success. As a minimum, the following disciplines will be members of the Support Structures CDT:

- Team Lead
- Support Structure Structural Design
- Structural Design
- Manufacturing

8.1.1.11 Horizontal Test Facility Team. This team is chartered to develop a horizontal test facility per requirements stated in this project plan and in the HTF FRD.

8.1.1.12 Avionics and Electrical Systems PDT. The Avionics and Electrical Systems PDT is responsible for developing a low cost solution to flight propulsion avionics for the PTAl. Experiments include: propulsion controller, ground check-out computer, drive electronics (engine and MPS valves, and TVC), software and sensors. Additionally, some cabling and harnesses will be designed and built to support ground testing (not a low cost experiment). This CDT shall develop a Fastrac 60K Engine Instrumentation and Harness Component Specification and provide a verification report to document compliance with requirements. Key opportunities for cost reduction for hardware are in the innovative use of existing low cost manufacturing, use of COTS materials, use of common manufacturing techniques. Key opportunities for cost reduction for flight software development are modular design methodology which provides maintainability, reusability, test benefits and a reduced documentation set. The avionics PDT will use all MSFC and support contractor personnel to ensure success. As a minimum, the following disciplines will be members of the PDT:

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Team Lead  
 Controller Specialist  
 Sensors Specialist  
 Drive electronics Specialist  
 Software Specialist  
 Harnesses/Elect Integration Specialist  
 EEE Parts Specialist  
 Engine PDT Representative  
 PTA Systems Representative  
 EMI/EMC Specialist  
 Stress Analyst  
 Dynamics Analyst  
 Thermal Analyst  
 Material Selection Specialist  
 Manufacturing Specialist  
 S&MA  
 Safety Specialist  
 MSFC Quality Assurance Representative

#### 8.1.1.13 MGSE Component Development Team.

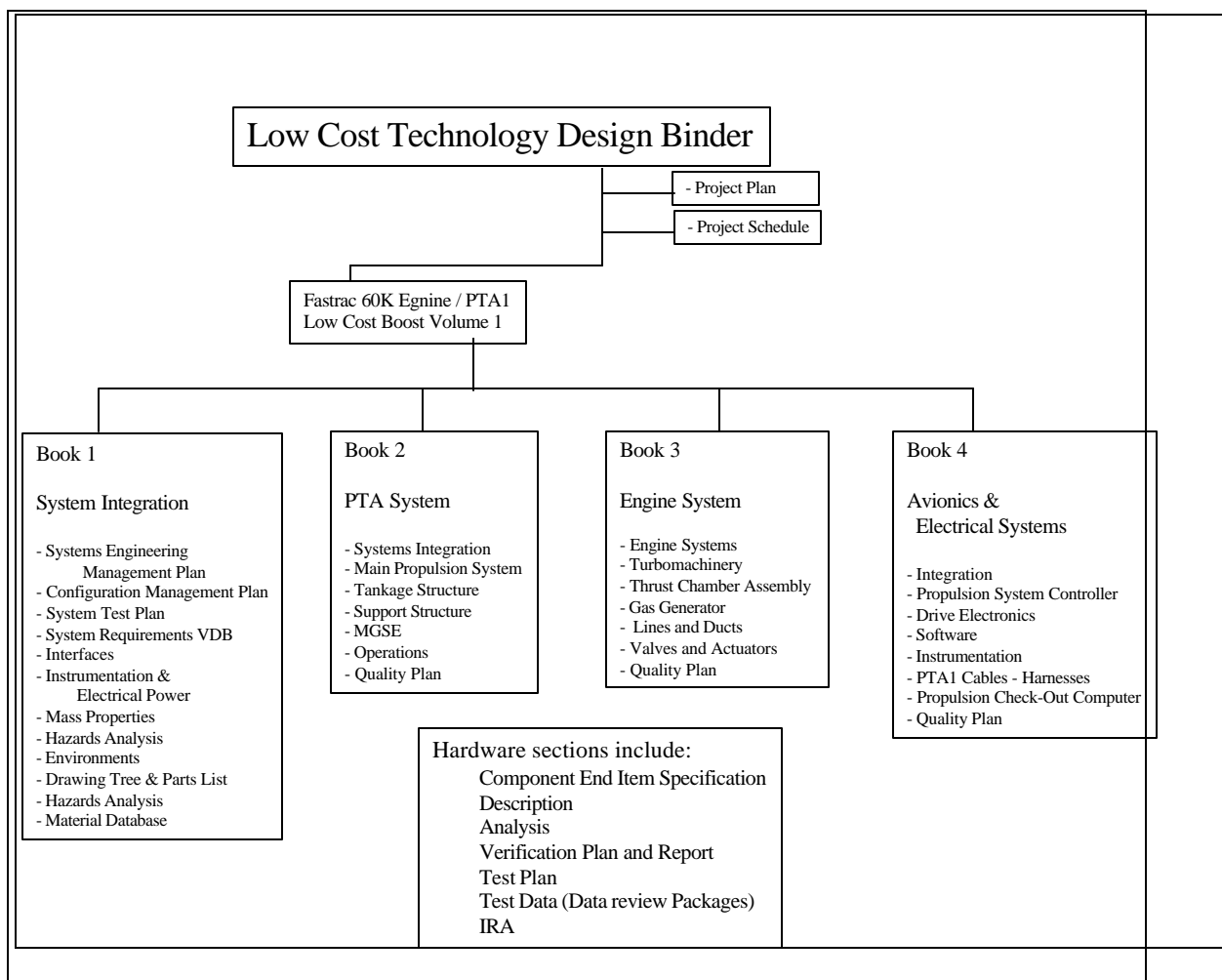
This team is chartered to design and fabricate the mechanical ground support equipment for the PTA1, the Fastrac 60K engine and any associated components MGSE. The MGSE CDT shall develop a MGSE and provide a verification report to document compliance with requirements. The MGSE CDT will select certification requirements per MSFC-P10.1-C02. This hardware will be designed to minimize the cost of the hardware associated with the GSE. Key opportunities for cost reduction are in innovative use of existing low cost manufacturing, use of COTS items and use of common manufacturing techniques. As a minimum, the following disciplines will be members of the CDT:

Team Lead  
 Mechanical Design  
 Test Facility Integration (Stennis Space Center Personnel)  
 Engine Systems PDT Representative  
 PTA Systems PDT Representative

8.1.2 Documentation. The FEP intends to contain the documentation of the Fastrac 60K Engine hardware,

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analysis, and design in a single electronic document referred to as the Design Binder (DB). This approach will minimize paper work and facilitate integration of the program. The layout of the Design Binders are as shown below in Figure 6.



**Figure 6. Design Binder Contents.**

The design binder will be located on an internet web site. The address is <http://138.115.11.73/LCT/>. Parts of this web page are password protected. To get the password, contact the Project Manager.

All information submitted to the DB must be approved and controlled by the appropriate team or board. The following is a list of documentation control

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requirements.

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<b>Document or Document Type</b>	<b>Baseline Control</b>	<b>Release Control</b>
Fastrac 60K Project Plan	N/A	STP Program Office
Interface Control Documents.	Level V Board	Level II Board
PTA1/60K Fastrac Engine Requirements/Verification/Compliance Database	Level V Board	Level II Board
System Test Plan	Level V Board	Level IV Board
Configuration Management Plan	Level V Board	Level IV Board
Component/System Drawings	Level V Board	Level IV Board
Component/System Specifications and Compliance	Level V Board	Level IV Board
Certification Plans	Level V Board	Level II Board
Component/System Analysis	CDT/PDT Lead	N/A
Component Test Plans	CDT/PDT Lead	N/A
Component Verification Report	CDT/PDT Lead	N/A
Quality Plans and Inspection Requirements	Level V Board	Level IV Board
Material Database	Level V Board	N/A
Integrated Risk Assessment	Level V Board	N/A
System Loads and Environments Document	Level IV Board	Level II
Structural Assessment Plan	Level V Board	

**CHECK THE MASTER LIST—VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE**

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Documents requiring only CDT/PDT Lead for control shall be generated by the PDT or CDT and submitted to the DB by the team lead. Only documents found in the DB are considered official. The user, via comparison to the DB, must verify all other copies as current. The team lead shall ensure the latest document is in the DB. Changes are controlled by the PDT/CDT lead through the team meeting process.

Documents requiring Level V Board or Level IV Board control shall be release and controlled per the Fastrac/PTA1 Configuration Management Plan. The board secretary shall submit baseline and released documents to the DB as a matter of procedure.

Documents subject to Level II shall be released and controlled by the STP Configuration Management Plan, ISO-STP-02. The board secretary shall submit baseline and released documents to the DB as a matter of procedure.

Drawings shall be maintained in the AIM system for Level V control and the MSFC repository for release through Level IV.

8.1.3 Design Criteria. In an attempt to facilitate rapid development and testing of experimental hardware, the project has categorized various levels of hardware fidelity. The goal here is to tailor the design and analysis process to match the fidelity of the test article. For example, robust or battleship hardware will not have the same analytical requirements as test flight hardware. Hardware categories are defined as follows:

- (1) Special Test Equipment - Test equipment needed to complete testing but not part of the experiment.
- (2) Concept Hardware - Test articles which are designed, fabricated, and tested solely for the purpose of enabling the design of a component. Usually battleship test articles used to prove a concept.
- (3) Development Hardware - Development hardware includes the components or systems designed, fabricated, and tested as a demonstration of conceptual design. This hardware is generally close to flight weight and is made using flight like

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manufacturing processes i.e. not battleship hardware. This category hardware is part of the "Low Cost Experiment" and should be of high enough fidelity to validate a design concept using COTS, low cost manufacturing techniques, etc.

(4) Test Flight Hardware - All components and systems designed and fabricated to be certified for flight tests.

(5) Qualified Flight Hardware - none in this project.

The level of analysis, inspection, and testing required for the hardware will be different for each category. Table I below is a listing of the minimum requirements for each category.

**Table I. Design Criteria.**

Hardware Category	Design and Manufacturing Standards/Process
Five - Qualified Flight Hardware	Strength and Fatigue - MSFC-HDBK-505A Fracture Control - MSFC-HDBK-1453
Four - Test Flight Hardware	PDT/CDT specified and project approved - Best commercial practices. NDE on a case by case basis
Three - Development Hardware	PDT/CDT specified and project approved - Best commercial practices. NDE on a case by case basis
Two - Concept Hardware	Designer Specified
One - Special Test Equipment	CDT specified and Project approved - Best commercial practice - GSE per MSFC-STD-126E

Each PDT will document in the Design Binder a test plan which defines the hardware category of each component and system configuration. While the PDTs/CDTs will determine material selection for their component, the material properties will be documented in Book 1 of the Design Binder. This will ensure that the PTAl hardware is analyzed using a consistent set of material properties. Such aspects of hardware monitoring as inspections, tests (proof, hot-fire, etc.), process control, process monitoring, and COTS hardware quality assurance required for each hardware category will be defined by the PDT and documented in the Fastrac Engine Quality Plan. For Category 4, fracture mechanics will only be done if a defect is found during inspection. In addition, a systems

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safety analysis will be done for the engine using critical items as identified by the engine CDTs. Based on the systems safety analysis, the engine PDT will determine the detailed inspections or design iterations required to reduce the risk of failure. For the first few units manufactured, it is recommended that the best available inspection methods be used. Based on inspection results of the first few units, the necessary level of inspections can be adjusted.

A detailed Structural Assessment Plan of the Fastrac 60K Engine shall be developed to describe structural assessment criteria for all products.

If the component or system configuration is changed to a higher category, the level of analysis and inspections required must be reassessed by the CDT.

8.1.4 Configuration Management. Configuration management (CM) will be controlled by the CE level 5 board for documentation baseline and the level 4 board for documentation release. These boards provide a disciplined method for establishment, control, accounting, and verification of the project baseline. The CM system helps ensure that technical requirements are identified and documented, accurately translated into the design, and that the design is translated correctly into hardware/software. The System Integration Team will develop a detailed Configuration Management Plan by per the following guidelines.

8.1.4.1 Objective. The configuration management approach used by LCT Project is tailored to facilitate development and test of experimental test hardware and is per MMI 8040.15. This approach will make use of the PDTs implemented on this project. Each PDT will follow the procedures shown below to:

Identify and document the technical requirements of all products.

Control changes, deviations, and waivers to these technical requirements.

Record and report change processing and implementation status.

Verify change incorporation.

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Verify performance, design, and configuration through design reviews and verification.

8.1.4.2 Scope. The configuration management approach listed above applies to a Category 1,3, and 4 hardware in all FEP products (see Section 5). Category 2 hardware will be controlled by the design organization. To provide configuration control for the X-34 Engine interfaces, a Level II board will be established as shown in section 5.0.

8.1.4.2.1 DRAWING RELEASE. Figure 7 Drawing Release Approach and Responsibilities, illustrates the flow of configuration control from the design engineer to the manufacturer and implementation of experimental hardware.

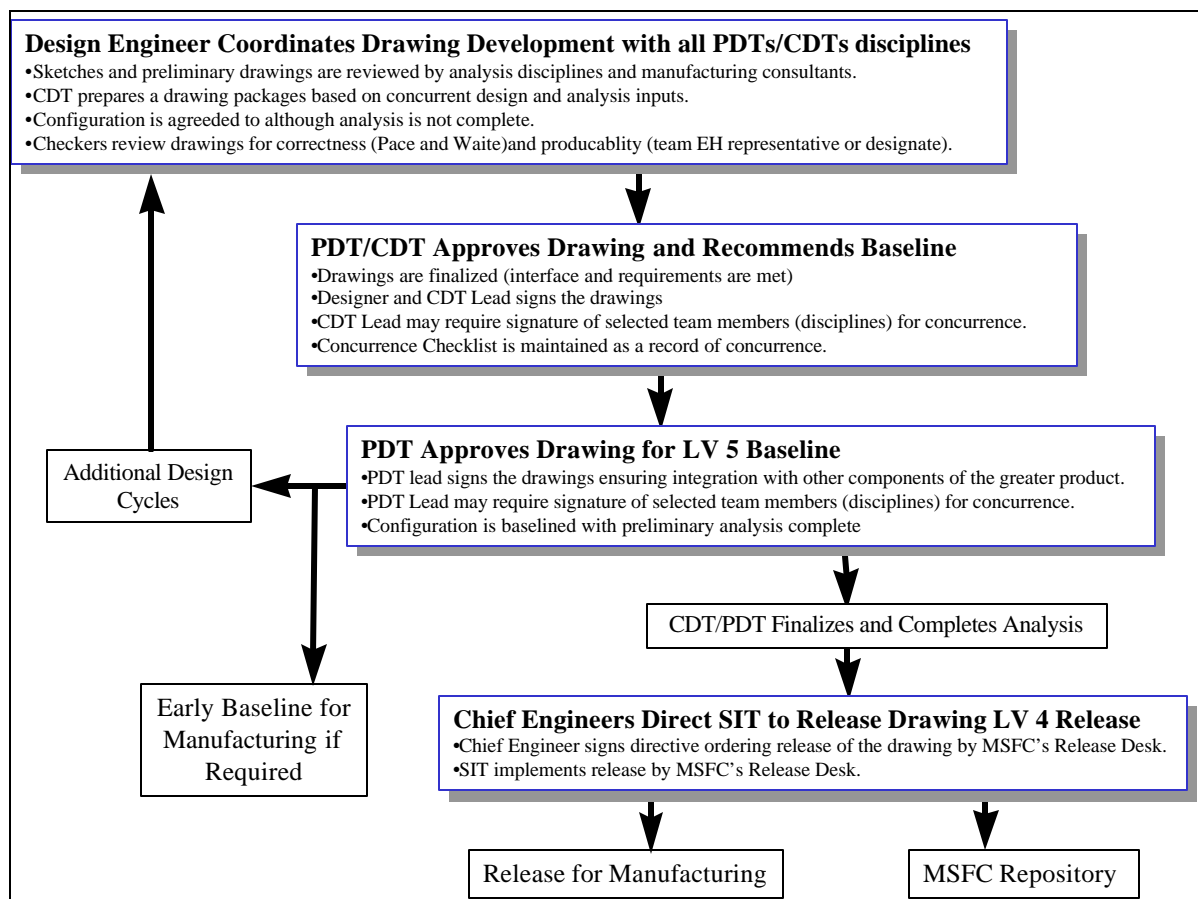


Figure 7. Release System.

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This Baseline/release approach allows for early manufacturing of components under the auspices of the PDT. If schedule requires early manufacturing the PDT lead can provide baseline drawings for manufacturing at risk to the Project. Baseline at the PDT level indicates that the configuration is understood and agreed to. Analysis is not complete but mature enough to indicate a potentially acceptable design. Hardware may be designated as scrap if significant design changes are required at a later date. The PDT baseline is also encouraged to reduce confusion in the PDT/CDTs as the design matures.

Final release occurs at LV4 and is administered by the CE. All drawings must eventually be released through this board. This release indicates complete drawings and analysis.

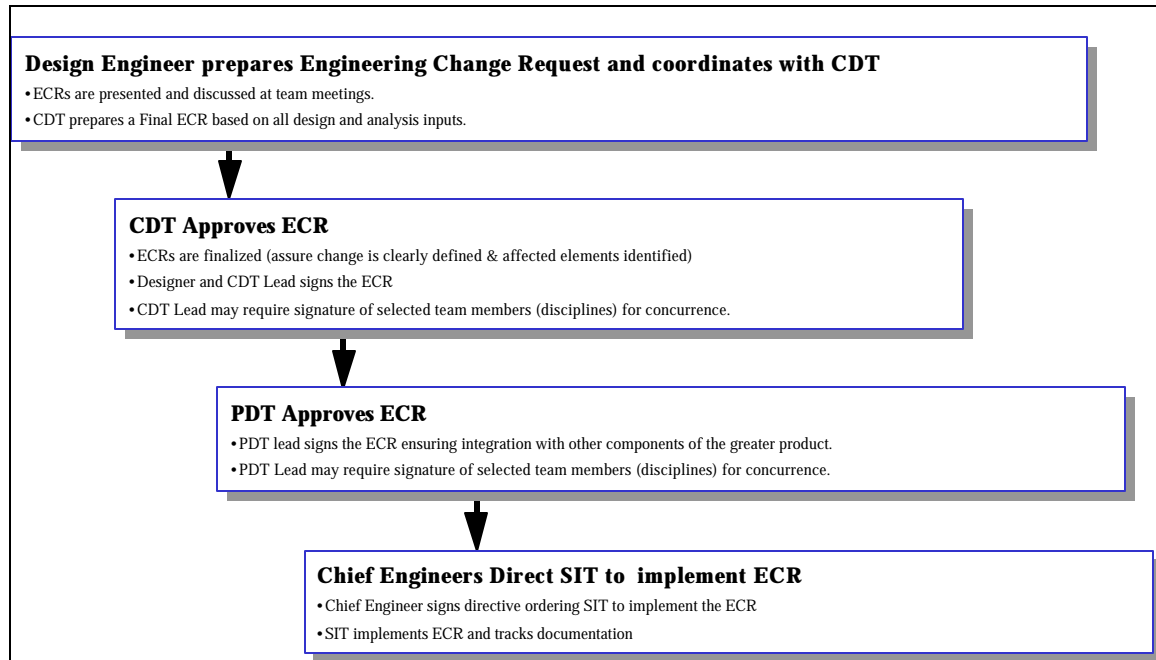
Note: February 18, 1999. Per direction from the Future X Program Manager an exception to Level 4 release requirements will be made and documented in a Discrepancy Acceptance Report. The Fastrac Engine Project is directed to release Fastrac Engine drawings prior to completion of the engine design analysis. This deviation is required for the procurement of engines needed to support additional flights of the X-34 vehicle(s). Drawings will be updated as necessary after the analysis is completed.

Vendor drawings will not be released by the PDTs or by MSFC's Release Desk. The vendors are responsible for their configuration control. Vendor drawings will be subject to review at PDR and CDR. Quality control representatives on the PDTs will provide oversight as required to ensure the hardware is correct.

8.1.4.2.2 DRAWING CHANGES. Engineering changes will be processed through as shown in Figure 8. The Engineering Change Request (ECR) process will be used to ensure that all changes to the baseline are coordinated, documented and available for future reference. All

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changes must originate with the designer and proceed through the CDTs and PDTs.

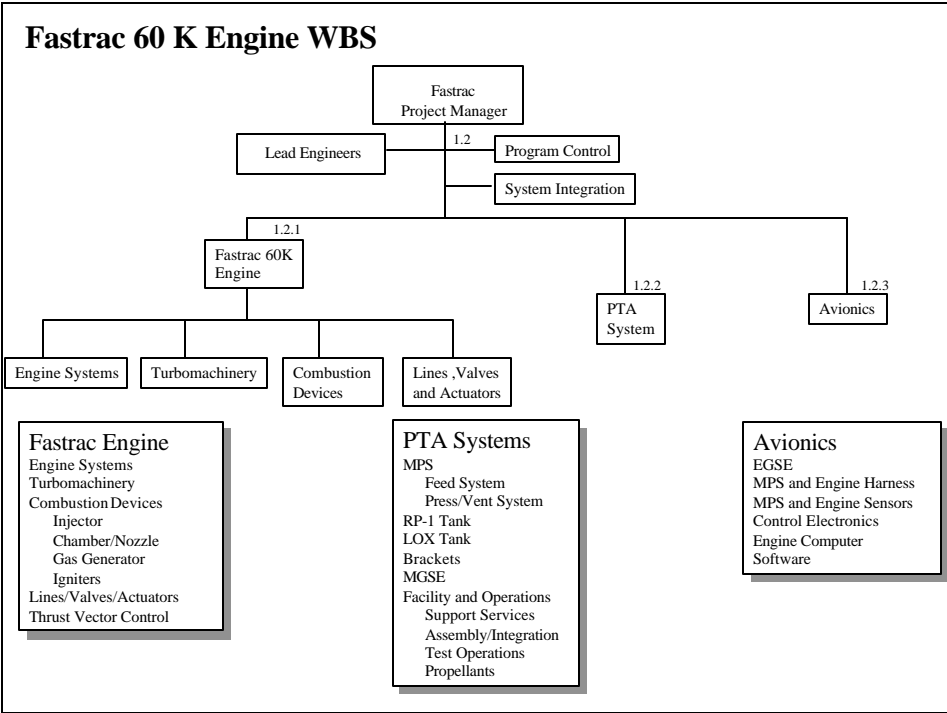


**Figure 8. Revision Control.**

8.1.4.2.3 DESIGN BINDER CONTROL. The Design Binder configuration control will be implemented by the CDTs and PDTs through the team meeting process. Exceptions are made for Level II documents and Level II and Level IV drawings contained in the DB. These document will be under configuration control through the MSFC release desk. All changes to other documents will be coordinated through the teams. Changes to baseline documents in the must be processed by a ECR.

8.2 Project Summary WBS. The Fastrac Project cost element are shown in the work breakdown structure shown below in Figure 9.

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**Figure 9. WBS.**

9.0           PROCUREMENT SUMMARY

Hardware design, analysis, and test support shall be primarily an in-house activity. Contracted personnel may be used for design and analysis with the permission of the Project Manager. Manufacturing will be procured from outside sources; however, in-house fabrication may be used when available. Chamber/nozzles will be fabricated using an in-house fabrication contractor in a facility dedicated to manufacturing research.

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**Table II. Anticipated Major Procurement Activities.**

<i>Element</i>	<i>Type of procurement</i>	<i>Type of contract</i>	<i>Source</i>
<b>1.2.1 Engine Systems</b>			
Fabrication or procurement of: turbomachinery small lines and brackets gas generator ignition system compn'ts avionics components MGSE Engine assembly	8a Set aside	Cost + Incentive	contract or
Fabrication of Chamber/Nozzles	Existing contract add on	N/A	In-House contract or
Fabrication of Injectors	Competitive - BOA	CPFF	contract or
Facility Mods/Propellant	Existing on-site Contracts		
Valve procurements	Competitive - Mid-range	TBD	contract or
<b>1.2.2 PTA Systems</b>			
Facility development	Inter-agency transfer	NA	SSC
RP Tank	Existing contract add on	TBD	In-house contract or
LOX Tank	Competitive - BOA	CPFF	contract or
Main Propulsion System	Competitive - Mid-range	TBD	contract or
<b>1.2.3 Risk Mitigation</b>			
Additional Hardware	8a Set aside	Cost + Incentive	contract or

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Additional Testing	Inter-agency transfer	NA	SSC
<b>1.2.4 Avionics</b>			
Components	Part of 1.2.1		
Small Purchases	Credit Card	NA	NA

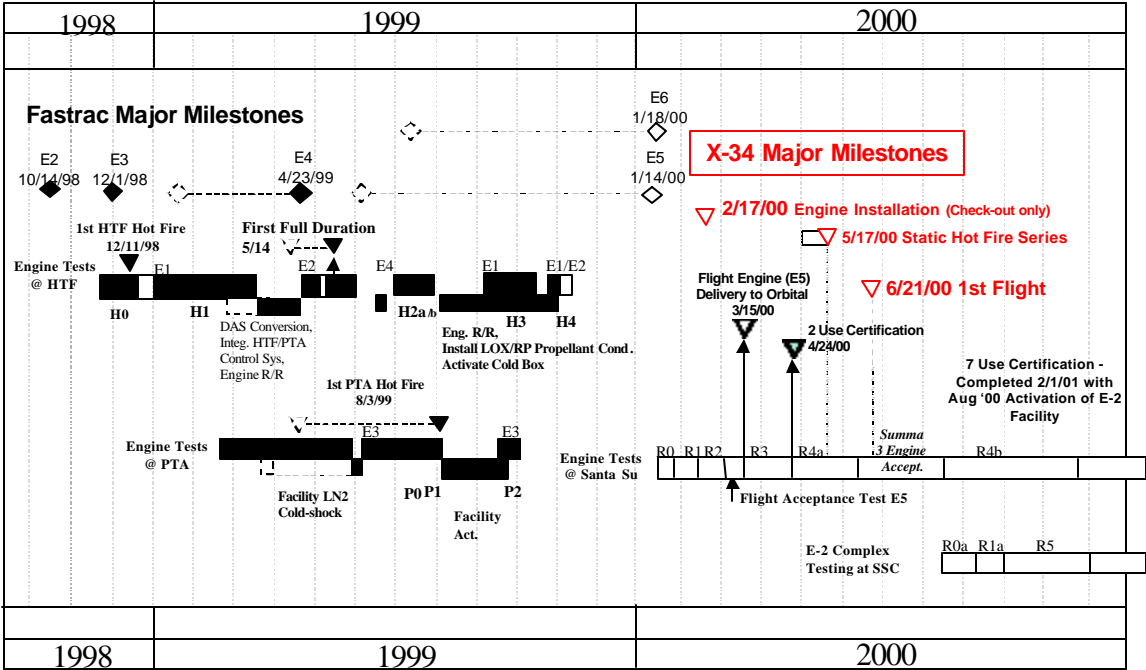
All hardware procuring activity and technical monitoring will be handled by MSFC. Test activity and facility procurements will be handled by SSC.

#### 10.0 SCHEDULES

Detailed Project Schedules will be developed and controlled by the Project manager and the current version shall be available in the DB.

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Table III. Major Milestones.



11.0 RESOURCES

Work force and funding resources required for implementation of this project plan are shown below.

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Table IV. PTA 1/Fastrac Cost Summary.

PTA1/Fastrac Cost Summary				Aug-98		
242-34-ZT & ZR						
\$/FTE-hr	57.7	58.9	60.1	61.3	61.3	
	FY96	FY97	FY98	FY99	FY00	Total
Planned In-Kind Labor (hr.)						
Fastrac 60K Engine	32004	103564	159804	137131	110736	543239
PTA1 Systems and Test Operations	8877	52396	74462	31378	28941	196054
Avionics	8772	40380	30804	28708	22962	131626
Integration (EL EO)				8508	7090	15598
					7958	7958
Planned Civil Service Subtotal	49653	196340	265070	205725	192706	909494
Planned Hours Cumulative	49653	245993	511063	716788	909494	
Planned FTE Cost (\$)	\$ 2,865,001	\$ 11,564,426	\$ 15,930,707	\$ 12,610,943	\$ 11,812,866	\$ 54,783,942
Planned FTE Cost Cumulative (\$)	\$ 2,865,001	\$ 14,429,427	\$ 30,360,134	\$ 42,971,076	\$ 54,783,942	
Planned FTE	23.9	94.4	127.4	98.9	92.6	437.3
Planned FTE Cumulative	23.9	118.3	245.7	344.6	437.3	
Planned Direct Cost						
Fastrac 60K Engine	\$ 4,350,400	\$ 3,045,700	\$ 6,272,000	\$ 7,818,000	\$ 4,218,000	\$ 25,704,100
PTA1 Systems and Test Operations	\$ -	\$ 6,860,000	\$ 4,315,000	\$ 4,661,000	\$ 3,583,600	\$ 19,419,600
Avionics	\$ 131,500	\$ 3,016,500	\$ 461,500	\$ 125,000	\$ 240,000	\$ 3,974,500
System Engineering Support	\$ -	\$ -	\$ 180,000	\$ 70,000	\$ 140,000	\$ 390,000
CM and Design Binder (SAIC)					\$ 36,000	\$ 36,000
Total Planned Direct Cost (\$)	\$ 4,481,900	\$ 12,922,200	\$ 11,228,500	\$ 12,674,000	\$ 8,217,600	\$ 49,524,200
Total Planned Direct Cost Cum (\$)	\$ 4,481,900	\$ 17,404,100	\$ 28,632,600	\$ 41,306,600	\$ 49,524,200	
Planned Headquarters Tax		\$ -	\$ -	\$ -		\$ -
Program Reserves		\$ -	\$ -	\$ -		\$ -
Total Planned Full Cost (\$)	\$ 7,346,901	\$ 24,486,626	\$ 27,159,207	\$ 25,284,943	\$ 20,030,466	\$ 104,308,142
Total Planned Full Cost Cum (\$)	\$ 7,346,901	\$ 31,833,527	\$ 58,992,734	\$ 84,277,676	\$ 104,308,142	

Detail lower level budgets are maintained by the Project Manager. Each PDT is responsible for developing their product within the budget guidelines.

## 12.0 MANAGEMENT REVIEWS

12.1 Program Reviews. The Project Manager will coordinate support of program reviews upon request.

12.2 Project Reviews. The following review milestones will be observed in order to incrementally develop a product baseline. Review Item Discrepancies (RID) will be generated by a review team assigned by the Project Manager. The completed RID package will be maintained by the Engineering Directorate as a Quality Record per MPG1441.1 and held for a period of five years after the X-34 powered flight.

- Preliminary Requirements Review (PRR). Project requirements and schedule will be under configuration control after PRR updates are

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incorporated. Meeting minutes and actions with closures will be maintained as a quality record by the Engineering Directorate per MPG1441.1 and held for a period of five years after the last X-34 powered flight.

- Preliminary Design Review (PDR) will yield the Design Requirements Baseline - This baseline is established after completion of the PDR and consist of the system requirements (shown in Book 1 of the DB for PTA1). PDR will consist of review of all applicable sections of the Design Binder at the 50% complete level and all drawings complete to 30%. Meeting minutes and actions with closures will be maintained as a quality record by the Engineering Directorate per MPG1441.1 and held for a period of five years after the last X-34 powered flight.

- Critical Design Review (CDR) will yield the drawing baseline - This baseline is established after satisfactory completion of the CDR. CDR will consist of review of all applicable sections of the Design Binder at the 100% complete level and all drawings 90% complete. The Product Baseline occurs after satisfactory completion of the manufacturing of the product and satisfactory documentation of the as built configuration. Meeting minutes and actions with closures will be maintained as a quality record by the Engineering Directorate per MPG1441.1 and held for a period of five years after the X-34 powered flight.

- System Level Test Readiness Review (TRR) will confirm the configuration of the test hardware and test facility, goals and procedure of the test, and concurrence of all involved parties. This is to be a level 2 review and minutes and actions with closures will be maintained as a quality record by the Engineering Directorate per MPG1441.1 and held for a period of five years after the last X-34 powered flight.

- Design Certification Review (DCR) will confirm that all requirements of the Certification Plan have been met. All DCR open issues must be closed prior to the Flight Readiness Review. Records required by the Certification Plan, meeting minutes and actions

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resulting from the DCR shall be maintained as a quality record by the Engineering Directorate per MPG1441.1 and held for a period of five years after the X-34 powered flight.

- Flight Readiness Review (FRR) will verify the system elements constructed for use, and the existing support elements are ready for test flight. This is a vehicle level review in which the Fastrac Engine will participate. This review shall be scheduled and conducted by the X-34 Project. The engine section of this review shall be a Level II review. Meeting minutes and actions with closures will be maintained as a quality record by the Engineering Directorate per MPG1441.1 and held for a period of five years after the X-34 powered flight.

A Design Review Plan will be prepared by the SIT for each review consistent with MPG 8060.1. The reviews will include the following: (1) kick-off meeting, (2) documentation/drawing review, (3) Preboard, and (4) Board. The kick-off and documentation review will consist of team members, leads, and line organization as defined in each group (total approximately 75 reviewers). The Preboard will consist of technical supervisory-level personnel and will be chaired by the Chief Engineer. The Board will be made of the next higher level of management and will be chaired by the Project manager (total approximately 10). The Board will meet only if there are unresolved issues from the Preboard.

### 13.0 CONTROLS

Not Applicable

### 14.0 PERFORMANCE ASSURANCE

#### 14.1 General.

14.1.1 Verification. System level verification requirements shall be documented in the PTA1/60K Fastrac Engine Requirements/Verification/Compliance Database. Compliance data will be formatted and supplied to the SIT by the PDT/CDTs via verification reports required for

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their products. Compliance data pertaining to this document shall be maintained by the the Engineering Directorate as a quality record per MPG1441.1 and held for a period of five years after the last X-34 powered flight. Engine specification verification requirements shall be documented in the Fastrac 60K Engine Specification. Compliance data shall be formatted by the Engine PDT and included in the verification section of the Fastrac 60K Engine Specification. Compliance data pertaining to this document shall be maintained by the Engineering Directorate as a quality record per MPG1441.1 and held for a period of five years after the last X-34 powered flight.

Component specification verification requirements shall be documented in the component specifications. Compliance data shall be formatted by the CDTs and included in the verification section of the component specification. Compliance data pertaining to this document shall be maintained by PDT/CDT lead.

14.2 Reliability. This project does not include enough hardware or tests to provide demonstrated reliability with significant confidence. There is no reliability requirement imposed on the experimental hardware.

14.3 Project Quality Policy. The Fastrac 60K Engine quality management system is the MSFC Quality Management System (QMS) described in MSFC Quality Manual, MSFC-MQM and subsequent publications. This document applies to all onsite process and operations for procurement, design, development, production, testing, and servicing of flight hardware, flight software, production units, qualification units, and associated flight support equipment, for which MSFC has responsibility.

The Fastrac 60K Engine is a flight system scheduled to fly on the X-34 vehicle per Memo of Agreement 8/22/96. This engine development project will comply with MSFC-MQM or subsequent presiding documentation except where pre-existing agreements and activities preclude compliance, such as requirements for contract review, purchasing, and

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control of the customer supplied product. Subsequent development activities will be subject to MSFC-MQM regulations. Hardware developed under pre-existing arrangements can be used for verification of fully compliant hardware. The Fastrac 60K Certification Plan shall specify these exceptions from the MSFC-MQM regulations. With these constraints engines 1-4 will be purchased under pre-existing procurement arrangements. Engines 5-6 will be purchased using procedures consistent with MSFC-MQM and the Fastrac 60K Engine Quality Plan. Exception to this may be negotiated on a case by case basis where long lead item procured and fabricated in the development program must be used to support X-34 Program schedules. The engine used to support the X-34 flight must come from the second lot, engines 5 through 6.

All PTA1, GSE, and avionics will be considered in scope because of the relationship to the flight X-34 Fastrac Engine and will comply with MSFC-MQM except where pre-existing agreements preclude. Each PDT is responsible for the development and implementation of inputs to the Fastrac Quality Plan. This plan must be compliant with MSFC-MQM and must be approved by the Project Manager.

14.4        Parts.        Per Project Quality Plan.

14.5        Materials and Process Control.        Per Project Quality Plan. Statistical methods will be specified by performing organizations and will be consistent with MSFC-MQM if applicable.

14.6        Performance Verification.        Performance requirements shall be documented by the SIT in the PTA1/60K Fastrac Engine Requirements/Verification/Compliance Database. Records of verification will be maintained by the SIT.

14.7        Contamination Allowance and Control.        Per Project Quality Plan.

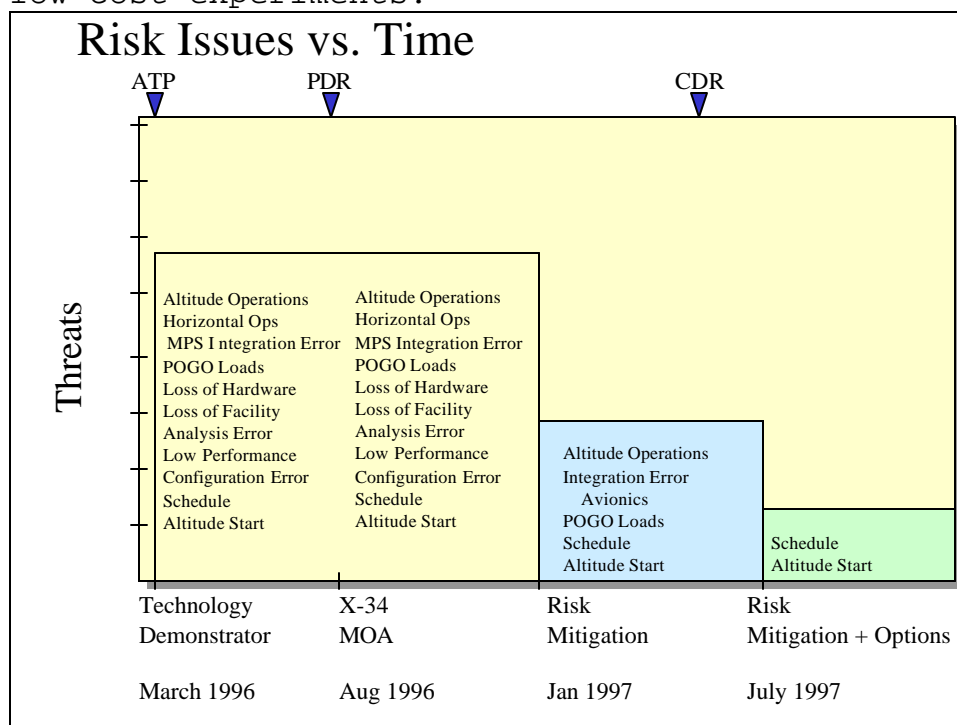
14.8        Software Assurance.        Per Project Quality Plan.

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#### 14.9 Maintainability TBD.

#### 15.0 RISK ASSESSMENT

Risk mitigation funding has been secured for this project. Figure 10 below illustrates the types of threats mitigated by additional analysis and test activity as the threats were identified in the development process. A separate engine test facility is added to minimize schedule impacts resulting from a loss of PTAl. This facility will also include simulation of the X-34 flight application and thus mitigate risks associated conditioning and starting the Fastrac 60K Engine at altitude. The facility will also integrate other elements of the X-34 propulsion system for system level tests. In some cases such as loss of hardware, additional components based on less risky design approaches are added to minimize the risk associated with low-cost experiments.



**Figure 10. Risk Reduction.**

Technical risks identified have been characterized as shown in Figure 11 below. This rational is used to

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prioritize risk mitigation funding. Table V list details of each risk considered.

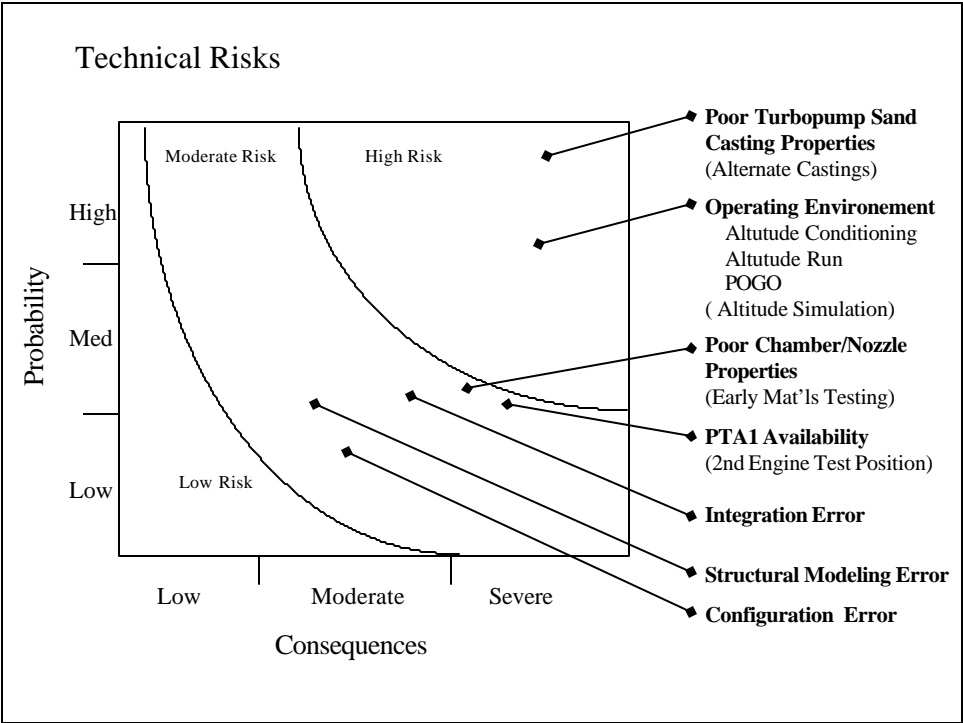


Figure 11. Technical Risk Priority

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**Table V. Technical Risks**

Technical Risks	Item	Issue	Mitigation
Physical Properties	Configuration Management	Informal Configuration Management baselined - risk schedule for corrective actions	Provide additional CM work force
Material Properties	Turbopump Castings Properties	Sand Cast housing baselined as a low-cost experiment - may not produce part with required properties	Parallel development of investment castings - process with known properties
	Chamber/Nozzle Material Properties	Silica phenolic properties not known at elevated temps - Combination of Si Ph and Graphite overwrap not known	Material Testing to provide typical properties of the materials over a range of temperatures
Radiation Prop'ts	None Identified		
Testing/Modeling	PTAI Availability	Loss of PTAI due to experiment failure	Parallel development of separate engine test stand
	Structural Modeling	Limited flight type analysis	Add detail finite element modeling where appropriate
Integration/Interface	MPS/Engine Integration	Conditioning and operation of propulsion system not demonstrated on ground until late in program	Add early integrated ground tests
	Avionics/Engine Integration	Flight Avionics	
	X-34/Vehicle ICD	Definition of interfaces incorrect	Add integration team
Software Design/Errors	No Special Risks Identified		
Reliability	No Special Risks Identified		
Safety	No Special Risks Identified		
Requirement Changes	No Special Risks Identified		
Fault Detection/Tolerance	No Special Risks Identified		

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Operating Environment	Engine conditioning during L1011 Flight to drop point	Engine compartment at 38,000 ft for 2.5 hours prior to start. Horizontal orientation and thermal issues drive design	Provide simulation of pre-start conditioning - thermal and horizontal
	Altitude Start	Engine must ignite during free-fall from L1011 at 38,000 ft.	None
	Altitude Run	30:1 Nozzle Expansion baseline but not ground tested	Provide simulation of altitude run
	POGO Loads	Engine gains are unknown - cannot predict POGO susceptibility	Provide test data to characterize gains
Proven/Unproved Technology	Loss of PTAl	PTAl is an flexible experimental test article including tanks, feed system, & avionics - these could fail	Provide separated engine test stand
System Complexity	No Special Risks Identified		
Unique/Special Resources	No Special Risks Identified		
Hardware Aging	No Special Risks Identified		
Manufacturing Processes	No Special Risks Identified		
Quality	No Special Risks Identified		

## 16.0 ENVIRONMENTAL IMPACT

Covered by existing Environmental Impact Statement secured by MSFC and SSC.

## 17.0 SAFETY

17.1 Industrial Safety. Assigned Safety and Quality (S&MA) personnel will assist in preparation of a Safety Checklist and provide verification of compliance at the TRR. S&MA personnel will assist in all reviews and provide review and approve function to all drawing releases and changes as members of the CDT and/or PDT.

**CHECK THE MASTER LIST—VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE**

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S&MA personnel will assist in development of handling requirements needed in the logistic plan in the Design Binders. S&MA personnel will also provide surveillance, mishap investigation, training and certification and safety instruction as required during the design and test programs.

17.2 Range Safety. Range safety for the X-34 test flights will be provided by the X-34 Project.

17.3 System Safety. For category 1, 2, and 3 hardware a Safety Checklist for Tooling, Facility, and Equipment Design hazards analysis supplied by MSFC's S&MA organization will be filled out by the PDT/CDTs with the assistance of S&MA representatives. The check list will be made available electronically and will be kept as part of the Design Binder. A checklist will be completed for each individual test article prior to TRR. This checklist is in support of the Integrated Risk Assessment (IRA) Analysis (single point failure) being done for PTAL by the S&MA office and the PDTs. The IRA analysis will assure compliance with the minimum safety requirements in Table 1. Category 4 hardware, test flight hardware, will receive an IRA for single point failures and associated hazards analysis. All items will be assessed, but members of the CDTs and PDTs will identify the most critical items in their product design and assist S&MA to determine failures and causes of failures for each selected item. The product of the IRA analysis will be recommended controls to mitigate the identified risks. These controls will be documented in a IRA supplied by the S&MA Organization. Disposition of recommendations for the IRA analysis will depend on cost/risks assessment made by the LCT Project if cost or schedule is impacted. Otherwise the teams will determine the risk control. The IRA is also the basis for inspection criteria to be documented on the component drawings, analysis criteria required for drawing release, and for test requirements.

#### 18.0 SECURITY

Covered by existing organizations at MSFC and SSC.